

# Fuel Cells for Transportation Applications

## *A Practical View*

Energy Efficiency and Renewable Energy  
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Patrick Davis





## **QUESTIONS:**

**What's Special About Fuel Cells ?**

**What's Keeping Fuel Cell  
Vehicles From the Market ?**



# What's Special About Fuel Cells ?



*Fuel Cells*

## ***The Combination of Efficiency and Low Emissions***

- » **Energy Security - Higher Efficiency**
  - ✓ reduce dependence on foreign oil
  - ✓ reduce trade deficits
  - ✓ increases economic, political & military security
- » **Emissions - Very Low Emissions**
  - ✓ reduce air pollution
  - ✓ climate change mitigation
- » **Economy - Intense Commercial Interest**
  - ✓ increase jobs & international competitiveness
  - ✓ reduced expenditures on fuel



# Projected Fuel Cell Vehicle Performance (PNGV-Class Series Hybrid)



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## *Projected Mileage, MPG*

	Gasoline Fueled	Hydrogen Fueled
Urban Fuel Economy	79	101
Highway Fuel Economy	97	128
<b>Combined</b>	<b>86</b>	<b>111</b>

Note: Based on NREL/ADVISOR system modeling using target fuel cell efficiencies.

**108 mpg**





# Fuel Cell System Emissions



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***Hydrogen Fueled Vehicles*** - True zero emission vehicles, water is the only vehicle emission

***Reformed Fuel Systems*** - Systems running on gasoline, methanol, ethanol or natural gas will have very low emissions.

## Steady-state 10kW Gasoline Fueled Fuel Cell System Emissions

***No optimization for emissions, no exhaust clean-up***

	Tier 2 (g/mile)	10 kWe (g/mile)
NOx	0.05	0.007
CO	2.1	0.0002
NMOG	0.055	0.003*

\* Includes methane



# If the Technology is so Promising, What's Keeping Fuel Cell Vehicles From the Market ?



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There are significant technical and economic reasons that will keep fuel cell vehicles from making significant market penetration for 10 years.

- **Technical Barriers**
  - Platinum Usage
  - Durability
  - Air Systems
  - Start-up
  - Fuel Infrastructure
  - Cost
- **Economic**
  - Competition from other technologies
  - Fuel Cell Cost
  - Economics of fuel introduction

***The DOE Transportation Program Focuses on the Technical Barriers***



# Technical Barrier: Platinum Cost & Supply



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***Preliminary analysis by A.D. Little indicates current platinum requirements are too high to support significant market penetration***

Fuel Cell System Platinum Content					
Component	ATR	PROX	Tailgas Burner	Fuel Cell MEA	Total Pt
Weight (grams)	9	13	8	181	211
Cost*	\$115	\$175	\$105	\$2,450	\$2,844

***10% U.S. vehicle market penetration would exceed current world platinum production levels. Attainment of DOE 2004 goals for platinum loading would enable large market penetration. World platinum reserves are adequate.***



# Technical Barrier: Air Supply



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***Issue: Fuel Cells require air and we are not very efficient at supplying it or using it***

***Amount of  
air being  
pumped***



***Amount of  
air needed***



***Amount of  
Oxygen  
needed***



- **Net effect:**

- Inefficient use of air in the fuel cell stack lowers efficiency and enlarges the stack size, weight & cost.
- Air is supplied at 3 atm pressure, making the oversupply a burden on the compressor.
- No off-the-shelf compressor technology closely matches the requirements of the fuel cell





# Technical Barrier: Durability



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***Issue: The durability of membranes, electrode assemblies and fuel processing catalysts have not been demonstrated to 5000 hours***

- System components do not exist yet to test for durability (i.e., sensors, flow valves).
- Other components such as the membrane have not yet been demonstrated to be durable to 5000 in the harsh automotive environment.
- Test fleets will have to be demonstrated (i.e., CA Fuel Cell Partnership), identifying failure modes for future development - this is critical to allow the vehicle warranty for manufacturer risk mitigation.



# Technical Barrier: Start-up Time



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***Issue: Current fuel processors take minutes to start-up.***



- This attribute does not compete well with current production vehicles
- Ability to operate immediately would place a large demand on battery size (up to 5kWhr)
- Implications on fuel economy and emissions

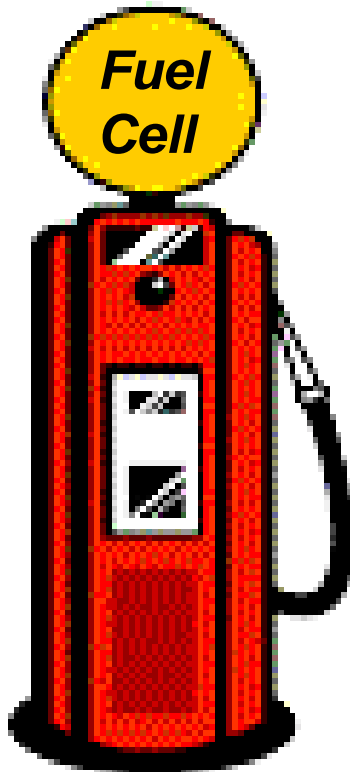


# Technical Barrier: Fuel Infrastructure



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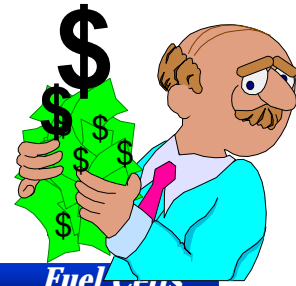
***Issue: For fuels such as methanol and hydrogen, significant infrastructure is required, for petroleum based fuels, a specialized blend***



- Methanol or hydrogen would fight the chicken or the egg problem.
- A petroleum fuel would probably require changes to today's gasoline - very low sulfur, reduced aromatics.
- On-board fuel processing is complex

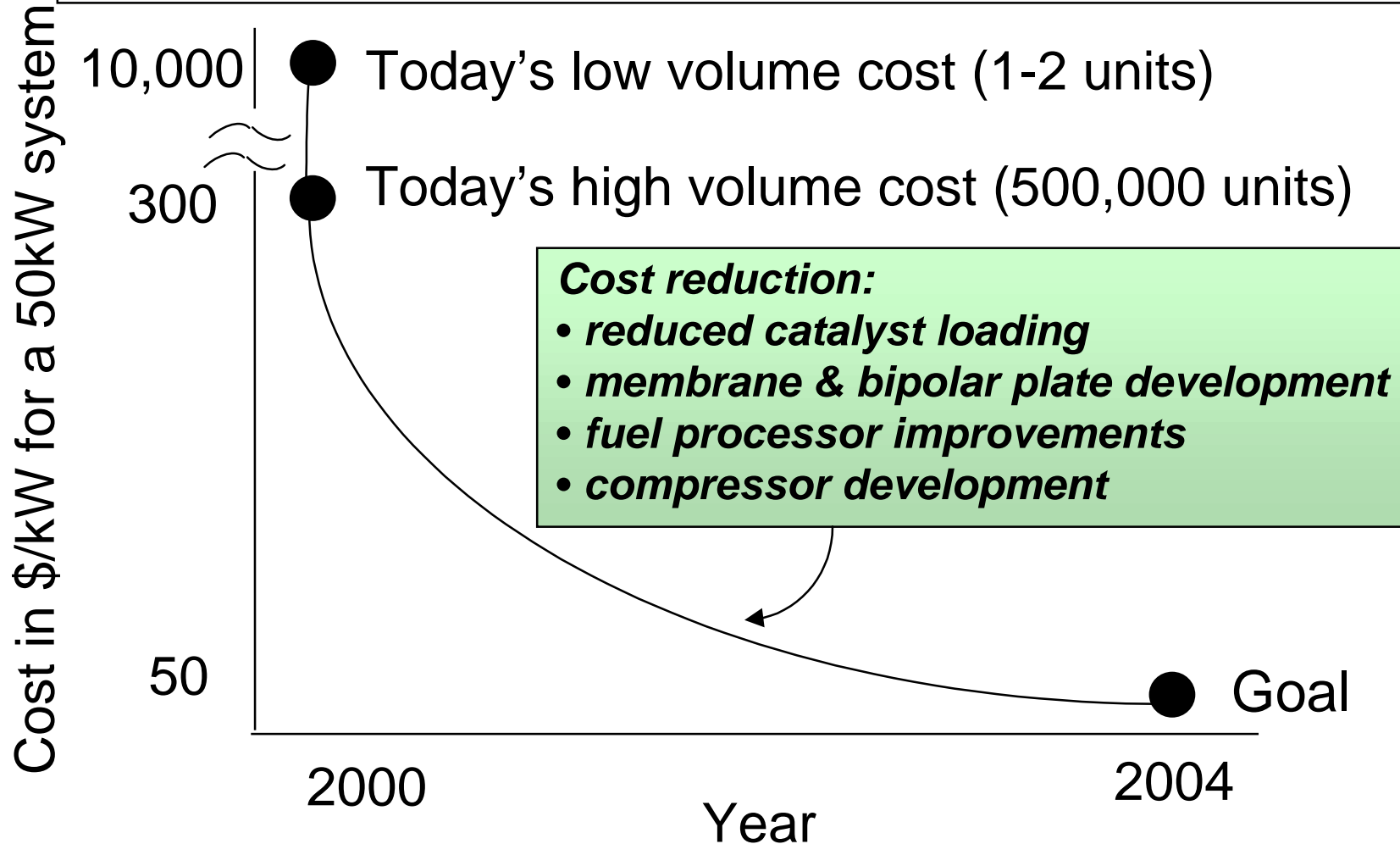


# Technical Barrier : System Cost



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**System = Stack + Fuel Processor + Controls/Ancillaries**





# Summary



## *Fuel Cells*

- Fuel cells offer the potential of high efficiency and low emissions for automotive powerplants
- The DOE Fuel Cells for Transportation Program focuses on R&D to remove technical barriers for PEM systems
- Major technical barriers include catalyst cost, air management, fuel processor start-up time, durability, system cost, and fuel infrastructure.
- Technical barriers will delay significant market penetration by approximately 10 years.